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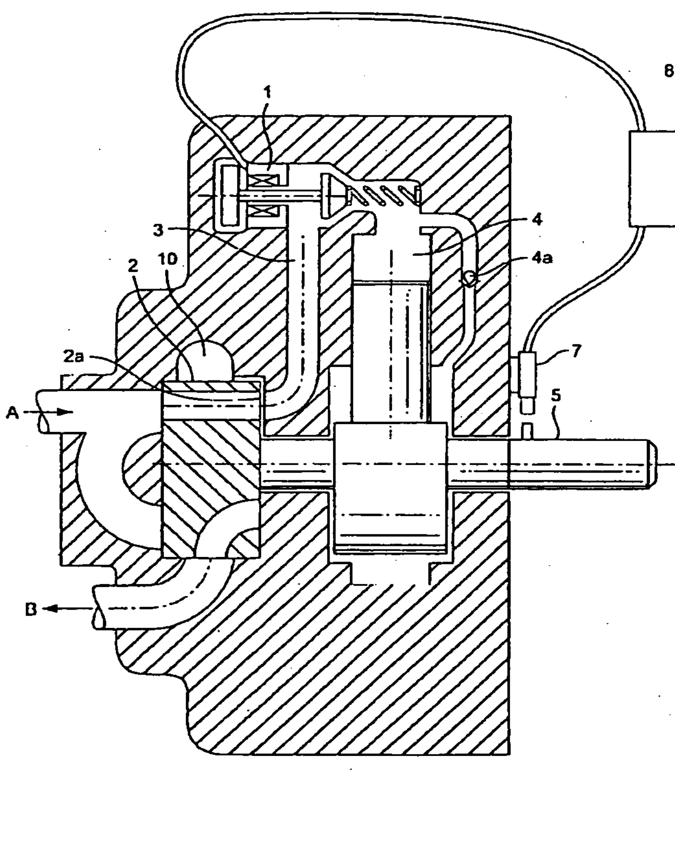
(54) Title: FLUID-WORKING MACHINE WITH DISPLACEMENT CONTROL



(57) Abstract: A fluid-working machine has working chambers (4), each of which is connected to a fluid commutating means (2) which alternately connects the working chamber to either of two fluid manifolds (A, B). An electronically controlled valve (1) is inserted into the flow path between each chamber (4) and the commutating means. This valve is commanded by a controller (6) receiving an input signal of the phase angle of the shaft (5) of the machine or at least one electronic pulse per revolution which informs the controller that the shaft is passing a known phase angle. The valve (1) allows overriding of fixed mechanical commutation by closing the valve cyclically, synchronised with the angular position of the shaft (5). Thus the controller (6) is able to vary the time-averaged fluid flow into or out of the machine by varying the proportion of chambers (4) which are isolated from or connected to the mechanical commutating means (2), to control the torque, speed, and/or fluid flow into and out of the machine.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Fluid-Working Machine with Displacement Control

Background to the Invention

[0001] This invention relates to a fluid-working machine. In operation of the machine the time-averaged flow of fluid is variable in all four quadrants of motion. The invention is applicable to any machine with working chambers, which alternately expand and contract, whether by pistons and cylinders, vanes, lobes or gears and where the primary method of commutating fluid to the working chambers is by a rotating port plate, synchronised to the phase of the chamber expansion and contraction cycle, which alternately connects high and then low pressure fluid manifolds to each working chamber.

Summary of the Invention

[0002] The invention provides a fluid-working machine according to claim 1. The insertion of a valve into the fluid connection between the commutating means and each of the working chambers allows each working chamber to be isolated from the commutating means. Chambers which are isolated in this way by the valve operate in an idle condition, whereby no useful fluid work is done by the chamber, and thus the displacement per revolution of the machine is reduced. In its simplest embodiment such valves may be controlled mechanically, allowing the machine to be used in a reduced displacement mode when it is desired, for instance, to operate at high speed. Such mechanical control may be automatic, for instance reducing the displacement of the machine as the speed of rotation increases above a threshold. Preferably the valves are individually controlled by an electronic signal, allowing each of the chambers to be isolated according to the command of an electronic controller. Preferably such controller has an input signal of the position of the shaft of the machine, allowing the timing of the valve actuation to be phased relative to the position of the shaft, allowing each chamber to be isolated from the commutator on a stroke-by-stroke basis. Preferred or optional features of the machine are set forth in the dependent claims.

Brief Description of the Drawing

[0003] A particular embodiment of the invention is described below in more detail, by way of example only, and with reference to the accompanying drawing, the single figure of which is a schematic section of a machine according to the invention.

Detailed Description of Particular Embodiment

[0004] The drawing shows a machine comprising a working chamber 4 in the form of cylinder containing a piston actuating a crankshaft 5. A conventional commutator plate 2 alternately connects the chamber 4 to port A or, via a toroidal cavity 10, to port B, one of the ports being a high-pressure port and the other a low-pressure port. As shown, the machine operates as a motor with fluid being supplied at high pressure at port A and exhausted at low pressure at port B, but both the pressures and the direction of flow could be reversed separately without changing the apparatus shown.

[0005] By placing an actively controllable on-off valve 1, in series with a rotating commutator plate 2, into the fluid passage 3 between the commutator plate and the working chamber 4, the flow into the working chamber can be controlled. When the machine is working with the shaft 5 rotating, and the on-off valve closed prior to the opening of the fluid inlet port 2a on the commutator, then the expansion stroke of the working chamber will occur in a partial vacuum. If the fluid is a liquid such as oil, a bubble is formed as air is drawn out of the liquid. The return stroke will collapse the bubble by the time the chamber returns to its minimum volume. In doing so the working volume will have exchanged no work with the fluid system while absorbing very little parasitic work. It is alternatively possible to avoid cavitation and air-release by fitting a fluid connection including a non-return valve 4a between the working chamber and the low-pressure line, possibly via the crank case as shown. Operating the working chamber with the on-off valve closed will result in an idle cycle.

[0006] When the valve 1 is left in the open position the working chamber functions, as normal, to produce a working cycle. The time averaged flow is varied by deciding on a chamber-by-chamber basis whether to effect idle or working cycles. The decisions are

taken as each successive chamber nears the minimum volume condition, irrespective of whether the machine is working as a pump or a motor. An electronic controller 6 senses the phase of the working chamber cycle using a once-per-revolution shaft sensor 7, an encoder, a resolver or some similar means. At times coinciding with the minimum working chamber volume the controller can either leave the on-off valve in its de-energised open state or pull it closed through electromagnetic means. In addition to the timing function, the controller reads the system demand, either through an analogue or digital input line or a bus 8, and decides whether the working chamber reaching the minimum volume condition should be left working or idled by closing the valve 1. In the embodiment shown, the on-off valve 1 defaults to the open position and is pulsed to close, but it is possible to see that the opposite operating mode, i.e. default closed, pulse to open would also have application where a power-off freewheel characteristic was required.

[0007] The controller decisions can also be made entirely on the basis of shaft speed in order to limit the rate of increase of shaft power. In such a mode of operation the electronic controller would require no external demand signal and would make the sequential on-off valve actuation decisions on the basis of a pre-programmed flow versus speed function.

[0008] In the instance of a vehicle propulsion circuit, where external demand signals are read by the electronic controller, the decision sequence can be determined in order to limit individual wheel slip, to create a skid steering effect or to create graded changes in torque and thus controlled vehicle accelerations.

CLAIMS

1. A fluid-working machine with variable volume working chambers, each of which is connected to a fluid commutating means which alternately connects the working chamber to either of two fluid manifolds, wherein a valve member is inserted into the flow path between each chamber and the commutating means.

2. A fluid-working machine as claimed in claim 1, wherein the valve member is electronically controlled.

3. A fluid-working machine as claimed in claim 2, wherein a controller for controlling the valve member receives an input signal of the phase angle of a shaft of the machine or at least one electronic pulse per revolution which informs the controller that the shaft is passing a known phase angle.

4. A fluid-working machine as claimed in claim 3, wherein the controller is arranged to choose whether to actuate the valve member, each time the working chamber volume is approaching its minimum, such that the valve is closed at a time close to the time the working chamber begins its expansion stroke, if it is desired to isolate the working chamber from the commutating means.

5. A fluid-working machine as claimed in claim 4, wherein the controller sums the previous flow demand to create a total displacement demand and compares it with the actual displacement through the machine over the same time period to determine the displacement error and the controller chooses either to isolate the working chamber or to leave it active in order to minimise the ongoing accumulated displacement error.

6. A fluid-working machine as claimed in claim 4, wherein the controller reads a demand from an external signal line and decides whether to isolate working chambers, as they reach the minimum volume condition, in order to regulate one of speed, torque, volumetric flow rate, power and volume displaced per revolution.

7. A fluid-working machine as claimed in claim 4, wherein the controller makes decisions to isolate working chambers on the basis of sensed shaft speed so that the ratio of working cylinders to idle cylinders decreases, according to a pre-determined function, as the machine speeds up, in order to either maintain a constant level of throughput flow or one which rises less quickly than the shaft speed increase would indicate.

8. A fluid-working machine as claimed in claim 3, wherein the machine is arranged to work as a motor, and the controller can choose to close the valve member some fraction of the way into an expansion stroke of the chamber, such that the chamber is connected to the commutating means for only a fraction of the expansion stroke, such that the volume of fluid working to drive the load in that expansion stroke is a fraction of the full geometric displacement of the chamber.

9. A fluid-working machine as claimed in claim 3, wherein the machine is arranged to work as a pump, and the controller can choose to close the valve member some fraction of the way into the expansion stroke of the chamber, such that the chamber is connected to the commutating means for only a fraction of a full working stroke, such that part of an expansion stroke consists of pulling a partial vacuum in the chamber, such that when a next contraction stroke begins, the chamber does not act as a pump immediately but at some fraction of the way into the contraction stroke, such that the contraction stroke displaces only a fraction of the full geometric displacement of the chamber into the commutating means.

10. A fluid-working machine as claimed in claim 3, wherein the controller is operable to reduce the loss of energy in the compressed fluid by closing the valve member just before the chamber reaches its maximum volume condition so that the remaining expansion can de-pressurise the fluid contained within the chamber before the commutating valve port is opened to the low-pressure manifold.

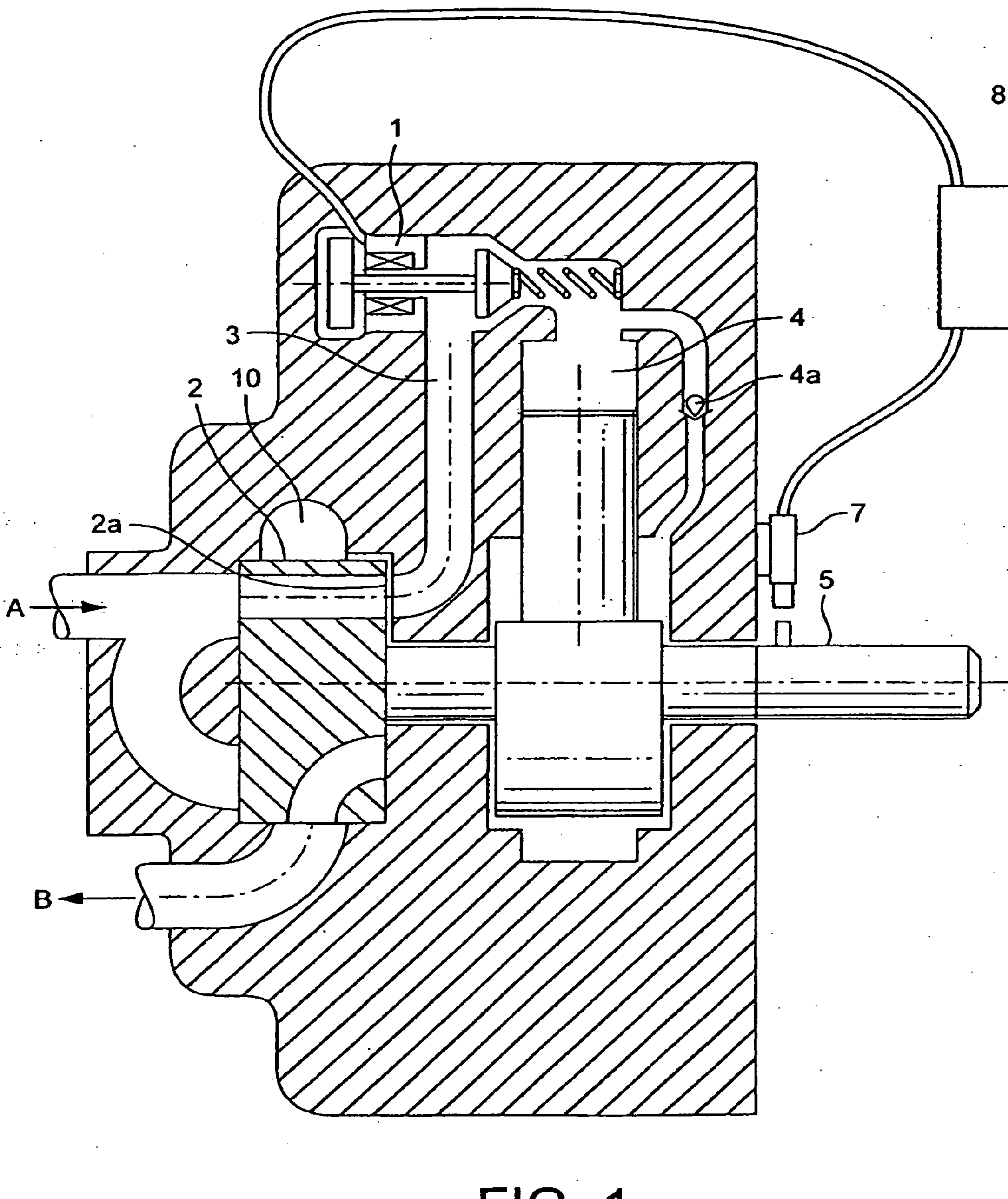

FIG. 1

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 456 581 A (JOKELA ET AL) 10 October 1995 (1995-10-10)	1
Y	the whole document -----	2-10
Y	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 09, 13 October 2000 (2000-10-13) & JP 2000 161204 A (CATERPILLAR INC), 13 June 2000 (2000-06-13) abstract -----	2-10
A	EP 1 319 836 A (CATERPILLAR INC) 18 June 2003 (2003-06-18) claim 1 -----	1
A	US 5 564 905 A (MANRING ET AL) 15 October 1996 (1996-10-15) column 1, line 58 - column 2, line 6 ----- -/--	1

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
4 July 2005	11/07/2005

Name and mailing address of the ISA	Authorized officer
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International Application No
PCT/GB2005/001235

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 162 022 A (ANDERSON ET AL) 19 December 2000 (2000-12-19) column 1, line 48 - column 2, line 13 -----	1

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